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The Origins and Evolution of Molecules in Icy Solids

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Astronomical observations of the past few decades have revealed the existence of a variety of molecules in extraterrestrial ices. These molecules include H2O, CO, and CO2, and organics such as CH4, CH3OH, and C2H6. Some ices are dominated by polar molecules, while non-polar species appear to dominate others. Observations, mainly in the radio and IR regions, have allowed the inference of other solid-phase molecules whose formation remains difficult to explain by gas-phase chemistry alone. Several laboratory research groups have reported on extensive experiments on the solid-phase reaction chemistry of icy materials, generally as initiated by either ionizing radiation or vacuum-UV photons. These experiments not only permit molecular identifications to be made from astronomical observations, but also allow predictions of yet unidentified molecules. This laboratory approach has evolved over more than 30 years with much of the earliest work focusing on complex mixtures thought to represent either cometary or interstellar ices. Although those early experiments documented a rich solid-state photo- and radiation chemistry, they revealed few details of reactions for particular molecules, partly due to the multi-component nature of the samples. Since then, model systems have been examined that allow the chemistry of individual species and specific reactions to be probed. Reactions involving most of the smaller astronomical molecules have now been studied and specific processes identified. Current laboratory work suggests that a variety of reactions occur in extraterrestrial ices, including acid-base processes, radical dimerizations, proton transfers, oxidations, reductions, and isomerizations. This workshop presentation will focus on chemical reactions relevant to solar system and interstellar ices. While most of the work will be drawn from that to which the speaker has contributed, results from other laboratories also will be included. Suggestions for future studies will be made, with an emphasis on some present deficiencies. The speaker's work has been generously supported by these NASA research programs: Cassini Data Analysis, Exobiology, Mars Fundamental Research, Outer Planets Research, Planetary Atmospheres, Planetary Geology and Geophysics, and the NASA Astrobiology Institute.

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